Appendix D

Geomorphological Evaluation

PEDOLOGY AND GEOMORPHOLOGY

OF THE CAUFFIEL CONNECTOR

NEW CASTLE COUNTY, DELAWARE

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Introduction

Pedological and geomorphological investigations of the area for the Cauffiel Connector located in the Bellevue section of Bellefonte, Delaware were undertaken for the purpose of interpreting paleogeographic histories of soils and landscapes relevant to usage by prehistoric peoples. Investigations were therefore directed toward examinations of soil geomorphic features for evidence of landscape stability, deposit ages, and site environmental conditions.

As an integration of the variables of land, climate and time, soil profile development allows for interpretations that are fundamental to paleogeographic analyses. Derived from the progressive climate-dependent weathering of geologic parent materials over time, soil profile characteristics provide tangible records of the past. Because soils owe many of their properties to weathering processes acting during extended intervals of relative landscape stability, the degree of soil profile development may be related to duration of deposit stability, and where sufficient subsoil formation has occurred, can suggest approximate ages for deposits. When most of the main factors of soil genesis are at least roughly definable, the tendency for soil formation to follow pathways normally culminating in predictable horizonation sequences provides a means of establishing chrono-stratigraphic markers even in situations where only truncated remnants of soil profiles remain in the stratigraphic column. Hence, within the context of soil-landscape relationships, soil profiles may be interpreted as indicators of depositional histories, erosional intervals, land surface ages, and environmental conditions.

Methods

Investigations were entirely of a field nature, and were undertaken on February 3, 1999. Efforts entailed pedestrian traversal of all major landscapes throughout the project tract, together with examinations and descriptions of soil profiles at selected locations. Soil profiles were examined by means of archeological shovel test excavations as well as hand auger borings. All profile locations were referenced to previously established transects and shovel test stations. A number of soil profiles were examined, and most were described in detail in accordance with standard (NRCS, NCSS) techniques and nomenclature for the field description of soils. These descriptions are contained in Appendix A.

Geologic Setting

The Cauffiel tract occupies a somewhat unique location in which elements from two physiographic provinces are intermingled to form a sector commonly referred to as the "Fall Zone." Within this transitional zone are landscapes and soils derived from both the native bedrock of the Piedmont as well as unconsolidated Coastal Plain sediments transported from elsewhere. No more than a kilometer or so northwest of the project tract Coastal Plain sediments are completely absent, and terrain is entirely of a Piedmont nature. South of the tract, however, the mantle of Coastal Plain sediments overlying the rock becomes so thick that both surface topography and soil composition are fully determined by them.

The geology of the Delaware Piedmont is dominated by Paleozoic to Precambrian age rocks that range in type from granite to gneiss and schist. These ancient metamorphic rocks underlie rolling upland terrain that has long borne the effects of geologic and pedologic weathering. So intensive has the weathering been that on gently to moderately sloping landscapes the upper mantle of soil and saprolite can often extend to depths of several meters. Even in instances of prolonged weathering, however, soil development is often a function of slope and landscape position. This is mainly due to the effects of erosion processes that are regulated by slope in response to climatic variables. Erosional processes are the most active on more steeply sloping terrain, and soil development beneath such surfaces thus tends to be less advanced than that typical for lower gradient, more stable positions. Indeed, the erosion and redepostition of soil materials both through natural processes as well as those attributable to man are the main mechanisms whereby appreciable changes have been introduced to what would be very ancient and otherwise mostly stable surfaces of the Piedmont.

Coastal Plain sediments consist of deposits of stratified, unconsolidated sediments that can range widely both in composition as well as age. Variously derived from ancient fluvial or marine systems, the regional sediments consist of basal Cretaceous marine deposits overlain by a variably thick and texturally diverse mantle of Quaternary deposits. Most of the Quaternary sediments were laid down by ancestral precursors to the Delaware River or other, often extinct drainage systems that would date well into the Pleistocene. Sediments of late Pleistocene or more recent origin are also common, particularly as surficial deposits. Of specific significance to the Cauffiel tract is the presence of a variably thick (0.5 to 1.5 m) surficial covering of silts that is very likely to be of loessial origin.

Glacial silts were carried to the region by the Delaware River in a distant time when the river's flow regime would have borne little resemblance to the current tidal system. Initially derived as "rock flour" ground by massive glaciers to the north, the silts were then transported downstream by meltwaters at the close of the Pleistocene. With seasonal fluctuations in glacial melting and flow volumes, exposed and drying mud flats would have periodically occurred along the river to provide a source of silt available for wind mobilization. This scheme thus places the onset of the loess deposition around the Pleistocene-Holocene transition at a time probably largely predating the arrival of humans in the region, and many thousands of years prior to the development of estuarine conditions.

What is now the Delaware River estuary was for most of the Holocene no more than an inland stretch of a strictly riverine valley. This now drowned valley probably contained a sequence of floodplain and river terrace landforms that have long since been destroyed or inundated by the Holocene sea level rise. Gradually progressing up the Delaware valley through the Holocene, encroaching brackish conditions would not have reached the nearby stretch of the Delaware River until about the last quarter of the Holocene. Thus it is only the later aboriginal inhabitants of the region that would have considered the project location to be a near-shoreline setting. For groups predating the Woodland period the Cauffiel tract would simply have been an interior position associated with tributaries draining to a distant freshwater Delaware River some one or more kilometers farther to the east. Assuming that the river has always been a focus for human activity, the project area could well have seemed remote to those earlier prehistoric people whose primary occupation centers were concentrated closer to the river.

Pedology and Geomorphology

Most soil differences across the tract can be attributed either to compositional variations related to the mixed site geology or more commonly to historic, mainly tillage-induced modifications as influenced by landscape position and degree of slope. The main landscape positions of the tract are variously sloping backslope and to a lesser extent lower lying footslope positions over which mostly silty soils are formed principally in the upper mantle of loess that blankets the project area. Other major soil parent materials were identified in only two of ten described soil profiles. These include saprolitic substrata intercepted at location W4, and gravelly Coastal Plain deposits in the prehistoric site area centered on location E12. Redeposited soil materials accumulated in low-lying footslope or toeslope positions subsequent to erosion and transport across the landscape are also present on the tract, particularly as slopes decline in their eastward approaches to Stoney Run. These deposits are overwhelmingly of historic age.

Prehistoric Period

With respect to site formation processes, the examined profiles reveal a record of soil genesis commencing in the Pleistocene tens of thousands of years ago and extending through the historic period. The profile of location W4 witnesses the greatest span of site history. Consisting of thick (74 cm) loessial silts atop a truncated residual soil, this profile is bisequal. The truncated residual profile is of little archaeological consequence but with respect to the changing Pleistocene environment, pedogenesis, and geomorphology, it gives dramatic testimony. Existing remnants represent the lower subsoil horizons of a very strongly developed soil formed from intensely weathered saprolite of the Piedmont. Only about the lower 37 cm of the former solum, identified as a 2BC horizon, are still present. With reddish colors (7.5YR 5/6-5/8, 5YR 5/6) and a clay loam texture, this lower transitional horizon suggests that the original residual soil would have contained a very strongly developed argillic horizon, probably of similar reddish coloration and clay texture. Additionally, the original solum was probably at least 1.5 m thick. Further soil formation in this material would have been halted by the loessial burial, so that all of the development would have preceded both the deposition of the loess as well as a major period of erosion that scoured the landscape prior to the introduction of the loess.

The exhibited degree of soil formation in the saprolite together with the severe erosion and subsequent burial by loess suggest the following paleogeographic sequence of episodes. At some interval in the Pleistocene a residual upland landscape with a minor Coastal Plain component along the Stoney Run valley existed at the site. The extremely advanced degree of development suggested by the remaining saprolitic 2BC horizon is indicative of a very prolonged period of relative landscape stability and soil formation. This would be incompatible with the cold and unstable climatic conditions of the late Pleistocene Wisconsinan glaciation, and the most likely scenario would therefore assign this soil a Sangamonian age. With the advent of the Wisconsinan glaciation and the attending climatic deterioration, the landscape became unstable, and a major period of erosion initiated landscape denudation. This may well have lasted through much of the Wisconsinan or it may simply represent a short, intense period. Whatever the duration of the erosional episode, however, it was terminated by the arrival of the loessial silts.

Coincidentally, the amount of loess laid down over the truncated residual soil appears to have just about matched the amount of soil previously eroded from the site. The present landscape topography may therefore have some resemblance to its residual Sangamonian precursor, although with erosion and variable thickness of the silt cap the relief has probably become somewhat more subdued, particularly since the arrival of Europeans. With completion of the loess deposition, a period of relative landscape stasis then began and continued through the Holocene

Based on the degrees of soil development exhibited by the examined soil profiles, a late Pleistocene to very early Holocene age can be assigned to all of the natural site landscapes and soils. In each of the examined soils including those formed in loess as well as the gravelly soil in the E12 area, well developed argillic (Bt) subsoil horizons indicative of 10,000 to 12,000 years of stable soil formation were present. This age is consistent with the presumed loessial origin of the silt mantle, and other than bioturbational mixing of the upper 25 cm or so, the land surface should be considered to have been essentially stable throughout the Holocene. Thus all human occupations of the site would have utilized the same surface, and unless subject to historic modification, all prehistoric artifacts should be confined to near-surface horizons.

Historic Period

The last major changes to the site were initiated in the historic period, and can be mainly attributed to the effects of land clearing and tillage. These effects have impacted near-surface horizonation to produce expected patterns across the landscape. Tillage-induced erosion of sloping landscapes results in the depletion of topsoil from higher landscape positions with subsequent deposition of the eroded soil along lower lying positions. This erosional pattern is essentially ubiquitous on cultivated uplands and is the norm for almost any region with a prolonged agricultural history. Under severe conditions erosional truncation can even result in substantial downward migration of the land surface, often to the extent that existing plowed surfaces may now be at levels which formerly corresponded to subsoil depths of a half meter or more below the original surface level. Conversely, deposition of eroded materials along lower landscape positions results in an aggrading surface wherein the original land surface is buried beneath variably deep deposits of historic slope wash.

Historic changes are variously expressed in different portions of the site. Some intentional grading and filling such as that associated with the former trolley line has occurred in isolated locations, but the most archaeologically significant modifications have resulted from the widespread effects of historic tillage. Each of the examined soil profiles outside of the drainageway in the southeastern corner of the tract contained readily identifiable plow zones (Ap horizons) evincing a history of at least a moderate amount of tillage. Erosional loss of soil and surface truncation is probably the most common landscape alteration attributable to historic plowing. Although the project area has not been severely eroded, the majority of the gently to moderately sloping backslope positions predominating across the tract have suffered some losses of soil. In the most severe cases, the plow zones of several of the examined soil profiles (W8, E9, E12, and E18) were observed to rest directly on subsoil argillic horizons. This is an indication of sufficient downward surface migration to allow the plow zone to engulf the uppermost subsoil layers. In other backslope observations (W1, W4, CL10, W23), however, the persistence of transitional upper subsoil (BE) horizons intervening argillic and surface horizons, indicated lesser amounts of soil loss. The extent of soil loss is generally a function of landscape position and degree of slope, with the most eroded positions typically occupying backslopes of over 5%. As a likely average, historic soil deflation over most of the tract is probably on the order of a modest 15 cm or less.

Depositional settings for the accumulation of eroded soil occur in two principal circumstances. These are along the lower footslopes and toeslopes leading to the drainageway basin in the southeastern corner of the tract, and in the more isolated settings of local swales or gullies that are scattered over some of the higher landscape positions. A good example of the first of these depositional situations is provided by the profile of location E6, where 82 cm of historic slope wash have buried the original surface of a poorly drained soil. An example of a more localized setting is at location E9. Here, although in a higher lying and well drained position, a local swale has trapped 60 cm of agricultural slope wash. Interestingly, the underlying original soil at this location has also been plowed, even to the extent that as indicated by an argillic horizon immediately beneath its plow zone, appreciable erosion of the original soil occurred prior to the wash accumulation. Quite possibly, after a long period of tillage and erosion the swale was eventually stabilized with a cover of grass that also enhanced its ability to trap wash materials subsequently carried into it.

The predominance of erosional conditions together with the late Pleistocene to early Holocene age of the original surface have important ramifications for potential artifact occurrences across all of the tract's well drained positions. In the poorly drained southeastern basin, artifacts should not be expected since prehistoric occupation would have been extremely unlikely in this swampy area. For everywhere else, however, the antiquity of the landform means that artifacts for all chrono-cultural periods would have been deposited on the same land surface with little or no potential for burial beyond that attributable to minor pedoturbation or artificial excavation. Thus, essentially all artifacts would have been exposed to disturbance from plowing, and artifacts over most of the site area can assume to have undergone some post-depositional displacement. This displacement could have entailed both vertical and horizontal movement. In the downward migration of eroding surfaces, artifacts would have accompanied the downward spatial retreat and would even have become concentrated as lag deposits remaining as finer soil particles were borne away. As a counter process vertical displacement would also have occurred in depositional positions, but in an upward direction. In this case artifacts would have undergone upward dilution as plowing mixed them with successive slope wash additions.

Whether downward or upward, the amount of vertical artifact displacement has in most cases been limited to much less than a meter. Horizontal displacement could, however, be well on the order of several meters. The main mechanism for this is simply related to the tendency for a soil mass to fall as much as a few centimeters downslope each time it is lifted and turned by moldboard plowing. Depending on field management practices this mechanism over a period of one or two centuries could account for lateral artifact displacements of as much as 2 to 5 meters. Some lateral movement due to water transport in local gullies is also a possibility.

Summary

The Cauffiel tract ranges across mostly upland terrain over which soils are developed in mixed lithologies of loessial silt, residual saprolite, and Coastal Plain sediments. Although much of the site topography may largely be controlled by basal residual rock of the Piedmont, nearly all soils are formed in an upper mantle of silt. Both the advanced degree of subsoil development as well as the presumed loessial origin of the silt dates the soils to a late Pleistocene or very early Holocene time frame. Underlying saprolitic horizons are of much older soils that were likely formed in Sangamonian time and then truncated by erosion during the Wisconsinan glaciation.

With the exception of the soil in the poorly drained basin in the southeastern corner of the property, all of the examined soil profiles exhibited evidence of previous, possibly long histories of plowing. It is this historic plowing that accounts for any archeologically significant soil changes across what are otherwise old landscapes whose topography and original surfaces were in place before the earliest arrival of humans in the region. Without the influences of historic land clearing and farming all prehistoric artifacts should therefore be at or very near the land surface, and indeed since the majority of the project area landscapes should be considered essentially erosional rather than depositional, a near-surface restriction for artifact distribution still applies for most of the tract. Only in limited depositional settings such as low-lying positions approaching the southeastern drainageway or in local upland swales has any burial of original surfaces occurred. The low-lying drainageway would have been too poorly drained for human occupation, but in the well drained upland swales artifacts could potentially be present beneath historic slope wash deposits as deep as 70 to 80 cm.

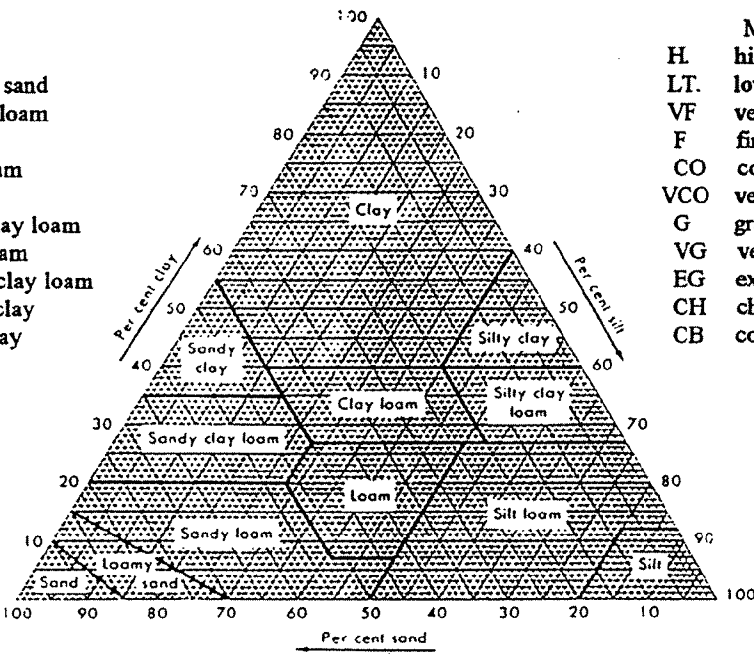
APPENDIX A

Soil Profile Descriptions

ABBREVIATIONS AND NOTATION

TEXTURAL CLASSES

Classes	
S	sand
LS	loamy sand
SL	sandy loam
L	loam
SIL	silt loam
SI	silt
SICL	silty clay loam
CL	clay loam
SCL	sandy clay loam
SC	sandy clay
SIC	silty clay
C	clay



Modifiers	
H.	high (heavy) clay %
LT.	low (light) clay %
VF	very fine sands
F	fine sands
CO	coarse sands
VCO	very coarse sands
G	gravelly
VG	very gravelly
EG	extremely gravelly
CH	channery
CB	cobbly

LOWER BOUNDARY

Transition Zone		Topography	
A	abrupt (<2 cm)	S	smooth
C	clear (2-5 cm)	W	wavy
G	gradual (5-15 cm)	I	irregular
D	diffuse (>15 cm)	B	broken

example:

CS = clear smooth

STRUCTURE

Grade		Size		Type	
0	structureless	F	fine	GR	granular
1	weak	M	medium	SBK	subangular blocky
2	moderate	CO	coarse	PR	prismatic
3	strong	VCO	very coarse	PL	platy
				SG	single grain
				M	massive

example:

1COPL = weak coarse platy

CONSISTENCE

LO	loose
VFR	very friable
FR	friable
FI	firm
VFI	very firm
EFI	extremely firm

DRAINAGE

VERY POOR	gleyed immediately below thick dark surface
POOR	gleyed immediately below surface
SOMEWHAT POOR	mottled 20 to 45 cm below surface
MODERATELY WELL	mottled 45 to 100 cm below surface
WELL	not mottled within 100 cm of surface
EXCESSIVE	well drained with sandy textures

MOTTLING

Abundance		Size		Contrast	
F	few = < 2% of area	1	fine = <5 mm	F	faint
C	common = 2-20% of area	2	medium = 5-15 mm	D	distinct
M	many = >20% of area	3	large = >15 mm	P	prominent

example: M2D = many medium distinct mottles

Report of Investigation

Client ______ Job No. ______ Described by DPW Date 2/3/9

Observation No. W1 Series ______ Type BORING
Physiography BACKSLOPE Slope/Aspect 2-3% Water Table ______
Drainage MODERATELY WELL Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap	0-22	SIL		10YR3/2			FR	
BE	22-40	SIL		10YR4/4			FR	
Bt1	40-75	SIL		10YR4/6			FR	
Bt2	75-90	SIL		7.5YR4/6	C2D	10YR6/2	FR	
BC	90-111	SIL		10YR4/6	M2D	2.5Y6/2	FR	
C1	111-140	SIL		10YR4/6	M2D	2.5Y6/3	FR	
C2	140-180+	SIL		10YR6/3	M2D	10YR4/6	FR	
						2.5Y6/2	FR	

Observation No. E2 Series ______ Type STP
Physiography FOOTSLOPE Slope/Aspect 3% Water Table 31 CM
Drainage SOMEWHAT POOR Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap	0-20	SIL		10YR3/2				
BE	20-30	SIL		10YR4/4				
Bt	30-40+	SIL		10YR4/6	C2D	10YR6/2		

Observation No. W4 Series ______ Type BORING
Physiography BACKSLOPE Slope/Aspect 4% Water Table ______
Drainage ______ Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap	0-20	SIL		10YR3/2			FR	
BE	20-41	SIL		10YR4/4-4/6			FR	
Bt	41-74	SIL/L		10YR4/6			FR	MIXED ZONE; SOME MICA
2BC	74-111	CL		7.5YR5/6-5/8,	5YR5/6		FR-FI	MICACEOUS RESIDUUM
2C	111-179	L		7.5YR5/6,	5YR5/8		FR	SAPROLITE
				10YR5/6				

Report of Investigation

Client ______ Job No. ______ Described by DPW Date 2/3/99

Observation No. E6 Series ______ Type BORING
Physiography TOESLOPE Slope/Aspect 2% Water Table ______
Drainage POOR Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
A	0-82	SIL		10YR3/2			FR	SLOPE WASH
Ab	82-97	SIL		2.5Y3/2			FR	
Eg	97-109	SIL		2.5Y5/3			FR	
Bt	109-118+	SIL		2.5Y 4/4	M2D	2.5Y6/2	FR	

Observation No. W8 Series ______ Type STP
Physiography BACKSLOPE Slope/Aspect 15% Water Table ______
Drainage MOD. WELL Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap	0-24	SIL	1MGR	10YR3/3			FR	
Bt1	24-40	SIL	2MSBK	10YR4/6			FR	
Bt2	40-60+	SIL	2MSBK	10YR4/6	C2D	10YR5/3	FR	

Observation No. E9 Series ______ Type BORING
Physiography BACKSLOPE SWALE Slope/Aspect 7% Water Table ______
Drainage WELL Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap1	0-19	SIL		10YR3/2			FR	
Ap2	19-60	SIL		10YR3/3			FR	SLOPE WASH
Ap3	60-73	SIL		10YR3/3			FR	POCKETS 10YR3/2; FLAKE
Bt	73-100+	SIL		10YR4/6			FR	

Report of Investigation

Client ______ Job No. ______ Described by DPW Date 2/3/99

Observation No. CL10 Series ______ Type BORING
Physiography BACKSLOPE Slope/Aspect 4% Water Table ______
Drainage ______ Remarks ______

Horizon	Depth	Texture	Structure	Color	Mottling		Consistence	Other Features
AP	0-20	SIL		10YR3/3			SIL	
BE	20-37	SIL		10YR4/4			SIL	
Bt	37-45+	SIL		10YR4/6			SIL	

Observation No. E12 Series ______ Type STP
Physiography BACKSLOPE Slope/Aspect 3% Water Table ______
Drainage ______ Remarks ______

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap1	0-15	SIL		10YR3/2			FR	
Ap2	15-24	SIL		10YR4/3			FR	
Bt1	24-49	GL		10YR5/6, 5/4			FR	ORGANIC TONGUES TO 34CM
Bt2	49-77	GH.SL		10YR4/6, 7.5YR4/6			FR	
2Bt	77-114	SCL-L		2.5Y4/4	M3D	10YR4/6	FR-FI	FEW GRAVELS
					C3P	5Y6/1		

Observation No. E18 Series ______ Type STP
Physiography BACKSLOPE Slope/Aspect 2% Water Table ______
Drainage MOD. WELL Remarks WASH TRAPPED BY TROLLY BED

Horizon	Depth CM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap1	0-15	SIL		10YR3/2			FR	—
Ap2	15-55	SIL		10YR4/3			FR	SLOPE WASH
Ap3	55-72	SIL		10YR4/3, 10YR3/3			FR	
Bt1	72-104	SIL		10YR4/6			FR	
Bt2	104-121+	SIL		10YR5/6	C2D	2.5Y6/2	FR-FI	

Report of Investigation

Client ______ Job No. ______ Described by DPW Date 2/3/99

Observation No. W23 Series ______ Type STA
Physiography BACKSLOPE Slope/Aspect 11% Water Table ______
Drainage ______ Remarks ______

Horizon	Depth cM	Texture	Structure	Color	Mottling		Consistence	Other Features
Ap	0-19	SIL	1MGR	10YR3/2			FR	
BE	19-26	SIL	1MSBK	10YR4/4			FR	10YR4/2 TONGUES
Bt	26-50+	SIL	2MSBK	10YR4/6			FR	

Observation No. ______ Series ______ Type ______
Physiography ______ Slope/Aspect ______ Water Table ______
Drainage ______ Remarks ______

Horizon	Depth	Texture	Structure	Color	Mottling		Consistence	Other Features

Observation No. ______ Series ______ Type ______
Physiography ______ Slope/Aspect ______ Water Table ______
Drainage ______ Remarks ______

Horizon	Depth	Texture	Structure	Color	Mottling		Consistence	Other Features